

Smith (J. L.)

THE CENTURY'S PROGRESS IN INDUSTRIAL
CHEMISTRY.

AN ADDRESS

DELIVERED ON THE OCCASION OF THE

CELEBRATION OF THE CENTENNIAL OF CHEMISTRY,

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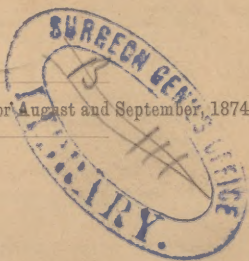
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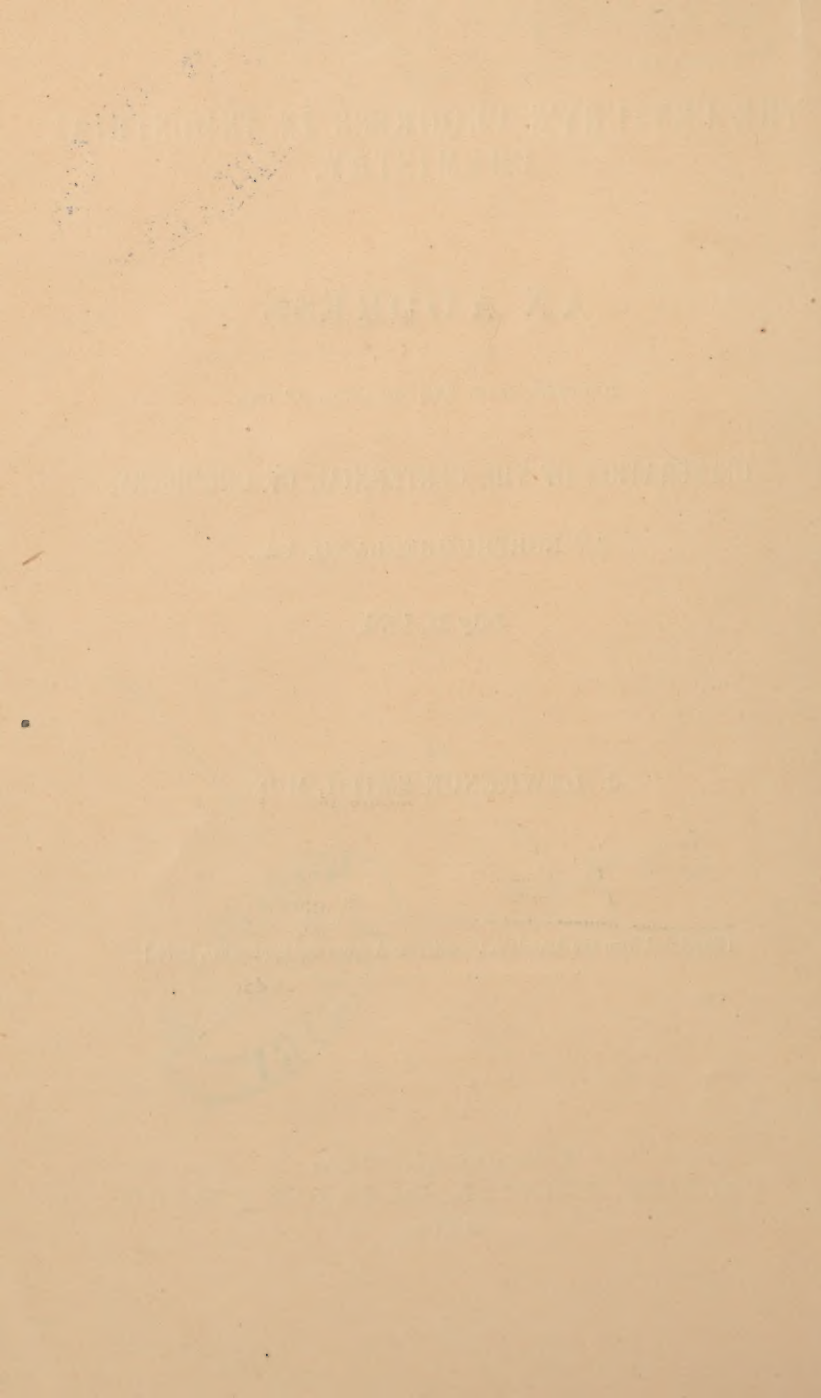
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THE CENTURY'S PROGRESS IN INDUSTRIAL CHEMISTRY.*

Chemistry was an art long before it was a science. But it was not until Priestley had discovered oxygen, and Lavoisier became the interpreter of chemistry with his great analytical mind, and the balance in his hand, did the daylight of chemistry truly dawn upon the world; previous to that time all was dim twilight, little better than darkness. When Lavoisier made the study of quantity an important element in chemistry, followed by Dalton's discovery of chemical proportions, then the inventive genius of mankind made chemistry a useful and certain servant, and built up one industry after another. As an art it has a pre-historic date; for whatever of the arts furnished products resulting from changes in the materials that nature furnished, and were produced by the reaction of one substance upon another, properly ranks as a chemical art; but it never began to assert its dignity as such until the sixteenth century, when that rude specimen of a scientific reformer, Paracelsus, undertook to deal with his contemporaries in a language more forcible than elegant, and in his violent denunciation of the medical men of his day he says:—

“After having studied Hippocrates, Galen, and Avienne, you think that you know everything, but you absolutely know nothing; you prescribe medicines, and you are ignorant of the method of preparing them! Chemistry it is that solves all problems of physiology,

* Much that is contained in this paper I have written at other times, when one or other of the subjects embraced had to be discussed by me.

J. L. S.

pathology, and therapeutics; outside of chemistry you only grope in the dark."

"Your Prince Galen is in hell; and if you knew what he had written to me from that place, you would make the sign of the cross with a fox's tail. Your Avienne is at the threshold of purgatory. O hypocrites! you will not listen to the voice of a physician instructed in the works of God; and after my death my disciples will expose your impositions, and show you to be but poisoners of Christian princes and gentlemen.

"Speak to me rather of chemists; they are not a lazy set such as you are, and are not clothed in velvet and silk, with rings on their fingers, and white gloves on their hands. They work night and day to get at their results; they do not frequent places of amusement, but pass all their time in the laboratory, and wear soiled clothes, are not afraid of burning and soiling their fingers with fire or filth; they are as black and sooty as blacksmiths and coal-heavers."

This was Paracelsus's theme, drunk or sober, and if history be correct, he was only sober when not in the first condition. In vigor and boldness he was a reformer of the type of his cotemporary Luther.

And from the age of Paracelsus, we may fairly date the epoch of that reform in the chemical art, which in the latter part of the eighteenth century culminated in the present *science of chemistry*, the result of hard labor and much self-denial.

All that is asked of me on this occasion is a review of a century's progress in industrial chemistry; to do this in an efficient manner, requires more time than is given to the celebration of this memorable occasion; to treat it otherwise, is but to give an imperfect enumeration of the wonderful applications of chemistry to those arts which have added so much to the prosperity, wealth, and well-being of the civilized world during the nineteenth century, which latter I must content myself with. In fact, industrial chemistry links itself with every modern art in such an intimate manner, that were we to take away the influence and results of chemistry, it would be almost like taking away the laws of gravitation from the

universe. Industrial chaos would result in one case, as material chaos would in the latter. The miner, the metallurgist, the machinist, the weaver, the paper-maker, the painter, the glass-maker, the fine arts, all draw from the rich storehouse of chemistry. To these we must add the new arts born directly from the same source, viz., photography, galvanoplasty, gilding and silvering metals, dyeing with new colors obtained from coal, vulcanized India-rubber, stearine candles, sugar from starch and wood, etc.

No one can paint in too vivid colors the sum of the indebtedness the civilized world is already under to the chemist, and no enthusiast can transcend in his wildest speculations what we are yet to realize. The chemical arts in their strictest sense do not simply aid the other arts, but they keep in activity a vast amount of capital, and consequently give employment to a large number of individuals, skilled and unskilled. In France alone, the annual value of chemical products is over \$250,000,000, of which \$125,000,000 represents the articles of sulphuric acid, soda, soap, India-rubber, and candles. Of chemical products, France exports \$20,000,000 worth, the remainder being consumed at home in giving activity to other industries whose products are largely exported in the form of woollen, cotton, and silk stuffs, etc.

The above statement represents the activity of industrial chemistry in but one country, yet every part of the civilized world is more or less engaged in the manufacture of chemicals.

It is not an easy matter to decide in what order to review the details of its progress, whether chronological or otherwise. I have, however, thought it best to adhere more or less to the former, without binding myself strictly by it. So I will call your attention first to the industrial chemistry of oxygen and chlorine, both elements of 1774.

Oxygen.

Oxygen, we are well aware, was first formed from dissociation of the elements of oxide of mercury through

the agency of heat, and from that time to this most of the processes for obtaining oxygen have this for their basis. There are no less than eleven methods of producing this gas practically.

1. By heating oxide of mercury—Priestley in 1774.
2. “ “ red oxide of lead.
3. “ “ nitrate of potash.
4. “ “ peroxide of manganese.
5. “ “ chlorate of potash.
6. “ “ sulphuric acid to a red } St. Clair Deville
heat. } and Daubray.
7. “ “ binoxide of baryta. }
8. “ “ oxychloride of copper. }
9. “ “ manganate of soda in the presence
of steam—perfected by Tessie du
Motay.
10. By decomposing chromic acid with sulphuric acid.
11. “ electrolysis.

But of all of these processes, only two or three of them may be said to belong to the domain of industrial chemistry, viz., heating chlorate of potash, sulphuric acid, oxychloride of copper, or manganate of soda.

For producing pure oxygen, the former is the one most commonly employed; for an impure oxygen, but costing much less, the latter method, by permanganate, is employed. There is one other development connected with oxygen during the past century: it is that of Schönbein, of giving to it a condition different to its ordinary one, approximating much nearer to chlorine than ordinary oxygen, and known under the name of ozone.

As yet oxygen in either of its conditions has received but limited application in the arts, but as the ready and economical method of producing it is of but recent origin, we must wait for the development of its industrial application. And my conviction is, that the day is not far distant when Priestley's name will not only be connected with the discovery of the corner-stone of modern chemistry, but will also be associated with one of the most useful agents in the chemical arts. Its

most important application is to the fusion of platinum in conjunction with hydrogen or hydro-carbon gases, and within the past few months a large ingot of 500 pounds of the alloy of platinum and iridium (used for making the standard meter for the different European and American governments), was fused by its use; in fact, no other known method could have been applied to give the required uniformity to the above alloy.

Chlorine.

I now pass to chlorine, to which this celebration belongs almost as much as it does to oxygen, and none of us can hear the name of Priestley pronounced, without our associating it in our mind with that of Scheele. To chemical industry and to the development of some of the most useful arts, the importance of the discovery of chlorine cannot be overrated.

When Scheele first described it, he seems to have studied all its properties, and left nothing for future chemists to develop, under this head, except his misconception of its true chemical position; which, of course, in no way affected the results of his investigation with reference to its reactions. The one property, however, which makes it so important an article in chemical industry, is its power of destroying organic coloring matter, by what is by many supposed to be an indirect process of oxidation. Thus the two elements discovered by the two great contemporaries, Scheele and Priestley, interweave themselves in their useful effects.

The present advanced condition of the art of bleaching was not the growth of a day. The following is a short summary of its growth. Berthollet in 1785 observes that an aqueous solution of chlorine, which had been discovered by Scheele in 1774, possessed the power of destroying vegetable colors, in the same manner as the gas itself. Berthollet showed the process to Watt at Paris in 1786, and Watt on his return to Scotland tried the plan on 1500 yards of linen in the bleach-fields of his father-in-law near Glasgow. It was brought under the notice of the bleachers at Aberdeen by Professor Copeland, and was introduced at Manchester about the

same time, chiefly through the labors of Dr. Henry. It was soon found that the texture of the goods was injured by the action of the chlorine, and that the workmen were much affected by the gas. Berthollet obviated these difficulties in a great measure by adding potash to the water, and Henry followed by substituting lime. About this period, the eminent manufacturer, Mr. Tennent, to whom we are indebted for the adaptation of this valuable agent to all the purposes of bleaching, took out his first patent for the manufacture of a saturated solution of chloride of lime, which he superseded by another patent, 1799, for the dry chloride of lime or *bleaching powder*, and this last we may regard as the greatest advancement since the discovery of chlorine, towards rendering it available in the arts, for it can now be transported readily to all parts of the world, and, moreover, we are indebted to this form (so to speak) of chlorine for the discovery and manufacture of that great boon to suffering humanity, viz., chloroform.

As regards the manner of making chlorine, no process has been devised since that of Scheele that is more ready or more economical, viz., the reaction of black oxide of manganese on chlorhydric acid or its equivalent, a mixture of common salt and sulphuric acid. Various processes have been devised for oxidizing the chlorhydric acid by mixing its vapor with air, and passing it over red-hot surfaces, but as yet none of these processes are adopted.

Let us see what chlorine has accomplished in its industrial application during the past century. Commencing with the agriculturist, it has stimulated the growth of cotton, and I believe that I am within bounds when I say that \$100,000,000 less of cotton would be made and sold in this country than is now the case, had chlorine not been discovered; a vast amount of the mineral wealth, in the shape of coal and iron, that has now enriched England for the past century, would have been still dormant in her mines, the buzz of the spindle, and the ceaseless racket of the loom, would have been far less than what it is; and why?

It is not sufficient simply to spin and weave cotton

to make it useful for the purposes of comfort and luxury—the cotton fabric as it comes from the loom is but a dingy and unsightly stuff—it must first be rendered as white as the driven snow before it becomes fitted for many of its uses. This in former times, as is well known to us all, was done by the agency of the oxygen of the air, the stuff being spread out on the greensward, or hung on rails, and moistened with water, a process requiring days and months, and a large surface of territory.

Chlorine has revolutionized this, and a few hours accomplishes that which formerly required days; and a few hundred square feet, containing properly constructed vats, takes the place of thousands of acres of land. Thus the civilized world has been able to use four or fivefold the amount of cotton than it otherwise would have done, and millions upon millions of acres of territory saved to the cultivation of grain and other necessities of life.

Perhaps I do not exaggerate when I say that one-twentieth the cultivatable territory is saved in England through the agency of chlorine, on the assumption that it could manufacture cotton, to the amount that it does, without chlorine.

So then, all hail to the industrial power of *Scheele's chlorine*, by its reaction on water developing the *oxygen of Priestley*. If chlorine has done thus much in the past century, she has a host of assistants around her scattering their beneficent influences, although the principal one savors strongly of brimstone.

Sulphuric Acid.

I allude to sulphuric acid, which cannot be said to have been known for more than three or four hundred years; but the industry, as it now exists, belongs to this century.

The process of manufacturing this acid, by the combustion of sulphur, now employed, is an English invention, and dates back to the early part of the last century. The first great improvement in its manufacture, during the past hundred years, was made by Dr. Roe-

buck, of Birmingham, in 1786. It consisted in the substitution of leaden for earthenware vessels, and all subsequent improvements in apparatus have been based upon the increase of the size of the recipient vessels, and improvements in the apparatus for burning the sulphur, and the manner of applying the nitric acid to the sulphurous acid, until the lead vessels have become immense lead chambers, and the apparatus for burning the sulphur have become furnaces.

Improvements of a secondary character, but yet of very great importance, have been added to the above. The principal one of these is the substitution of iron pyrites FeS_2 for sulphur, and the other is the substitution of platinum for glass vessels in the concentration of the acid.

The first use of pyrites is claimed for two parties, Dr. Manson and Mr. Hill. While the use of iron pyrites in the manufacture of sulphuric acid dates back prior to 1830, it was not until 1838 that the short-sighted policy of the King of Naples, in granting the monopoly of Sicilian sulphur to Messrs. Faix & Co., of Marseilles, fairly established its use, for the price of sulphur rose in England from \$25 to \$70 a ton; and in twelve months from that time, in England alone, not less than fifteen patents were granted for the manufacture of sulphuric acid from pyrites.

And although the monopoly was soon withdrawn, by the persuasion of English vessels of war, and the diplomacy of other governments, the pyrites had secured a firm footing in supplanting sulphur in the manufacture of sulphuric acid; and since then its use has rapidly increased, giving a wholesome lesson to governments to exercise great caution in granting monopolies, and in legislating so as not to thwart industries based upon a science that draws brilliant dyestuffs from coal, and is not to be confined in the manner and methods of its creations, so long as the elements in one shape or another are at its command.

Since the first production of sulphuric acid from pyrites, the establishment of Fahlun, in Sweden, has employed this process altogether, pyrites being very

abundant in that locality. This example was followed by Perret, of Chessey, France, where the pyrites contain from three to four per cent. of copper, which metal can only be extracted by desulphurizing the ore. From the mines of this locality seventy thousand tons of pyrites are used and exported annually, and the various lead chambers here for making sulphuric acid have a capacity of about 1,600,000 cubic feet. This process is carried on in all parts of France, whether the pyrites contain copper or not; and Sicilian sulphur is only employed for special purposes in France and England. I would here remark that so perfectly can the pyrites be now burnt, that there need not remain over one per cent. of sulphur in the residue.

It is not to be supposed, however, that sulphur is henceforth to be excluded from the manufacture of sulphuric acid; on the contrary, it is more than probable that many factories will return to its use, as the sulphur in Sicily is almost exhaustless; and if ever the country becomes opened to the world by good and numerous roads, the price of sulphur must diminish, and the diminution required is very small to bring it again into more common use among the acid manufacturers of the world.

The factories in Belgium, in the north of France, and in some other parts of that country, those in Germany, and a number in England, will find it profitable in almost any state of the case to continue the use of pyrites.

As regards the concentration of the acid, the great cost of platinum vessels is a serious drawback in its manufacture, but we are none the less indebted to the use of these vessels for the cheapening of the acid. Glass can be used in some places advantageously.

Efforts are now being directed to perfect a method of concentrating in vacuum, by which lead vessels can be used; but, up to the present time, with only partial success. Döbereiner's suggestion of making sulphuric acid in very much smaller apparatus than that now used (by the agency of sulphurous acid, air, and spongy platinum), has been tried and worked successfully on a

small scale, and its extended success belongs to the future of chemistry; the minor improvements, such as recovering the nitrous acid, etc., do not properly form a part of the review of the subject for such an occasion as this.

Bisulphide of Carbon.

Besides the use of sulphur for sulphuric acid in the chemical arts, it has of latter years been employed to no inconsiderable extent in making bisulphide of carbon, which is now manufactured on a very large scale, especially by the improved arrangement of apparatus of M. Deiss, placing a battery of four fire-clay cylinders, five feet high by twenty inches in diameter, into one furnace, and producing it at a cost of five cents per pound. Other forms of apparatus, however, are used to advantage. Some idea of the extent of its production may be inferred from the fact that several manufacturers make over a half ton each per day. It is used principally for dissolving and softening caoutchouc in the process of vulcanization; in the gutta-percha manufacture; in extracting bitumen from minerals by a process invented by M. Moussu; in extracting fat and oil from bones, oil cake, etc., sheep's wool, greasy refuse & stuff, as cotton waste, etc.; also used for the extraction of the aromatic principles of spices and other odoriferous plants, and, when perfectly pure, it is said that it can be used for extracting the most delicate perfumes from plants and flowers, without injuring the odors. It has also served as an agent for producing motive power, owing to its low boiling point, and engines have been worked successfully by it. In fact, much may be expected of it from its extended use in the future.

Soda.

From sulphuric acid my subject naturally glides into the history of the Industrial Chemistry of Soda, and, in referring to its origin, I will use the words of Hofmann and Ward: "The ever memorable discovery, by the illustrious Le Blanc, of the process now everywhere in use for manufacturing carbonate of soda from common salt, stands distinguished in the annals of industry, not

only as by far the most important of all chemico-industrial inventions, but also (a signal fact) of having been created perfect. All the other great chemical industries have been slowly worked out by the toil of successive inventors, but Le Blanc's process, the greatest of them all, remains to this day, what it was when he first gave it to the world, the best and simplest method of effecting the most valuable of all known transformations. Though eighty-six years have elapsed since this splendid discovery was made, and innumerable researches have been undertaken with a view to its improvement, the original indications of Le Blanc are all but universally followed, with merely a few comparatively unimportant modifications.

"It might have been expected that a process which, at its first introduction, was examined by a government commission of thoroughly practical men, and which, after having been submitted to comparative experiments, made with the greatest care, was recommended in an elaborate official report, would have been almost immediately adopted throughout Europe, with proportionate advantage to its discoverer. Such reasonable hopes, if entertained by Le Blanc, were destined to cruel disappointment. Le Blanc himself never reaped the reward of his admirable discovery.

"This man, who was certainly one of the greatest benefactors of his race, and to whom, long since, France and England should have joined to raise a statue, lived in poverty, and died in despair. The creator of incalculable wealth for his species, he wanted bread himself; and, after endowing man with cheap soda—that is, with the inestimable blessings of cheap glass and soap, cheap light and cleanliness, and a hundred collateral advantages—he was suffered, to the shame of Europe, to end his days in a hospital. There he lingered, a wreck in fortune, health, and hope, till reason herself gave way, and he perished madly by his own hand. It is to be hoped that with the advance of civilization these terrible tragedies, so frequent in past ages, will become more and more rare, till the future historians of progress shall be spared the pain and shame of recording any more

such outrages on justice—such ghastly martyrdom of genius.”

As the soda industry is the most gigantic chemical industry in its results upon the well-being of society, and the advancement of civilization, it is well to give a little history of it, as from its incipency to its present state it belongs to the past hundred years, and, besides, it is somewhat historic, too, in its relation upon the early recognition of the importance of the science of chemistry by great governments.

Early in the war of the French Revolution, France was cut off from her usual supply of soda, so requisite for many of its arts, as those of glass and soap-making, for at the time Spain supplied France with the soda she used, it being manufactured from the ashes of the seaweed.

The French Convention at that time issued a proclamation, which went on to say: “Considering that the Republic ought to extend the energy of liberty to all of the objects which are useful in the arts of first necessity, free itself from all commercial dependence, and draw from its own sources all the materials deposited therein by nature, so as to render vain the efforts and the hatred of despots, and should place equally in requisition for the general service all industrial inventions and productions of the soil, it is commanded that all citizens who have commenced establishments, or who have obtained patents for the extraction of soda from common salt, shall make known to the Convention the locality of these establishments, the quantity of soda now supplied by them, the quantity they can hereafter supply, and the period at which the increased supply can be rendered.”

In conjunction with the proclamation, a committee of four chemists was appointed in the first year of the French Republic to examine into all the processes devised for the purpose. The chemists were Lelievre, Pelletier, D'Arcet, and Giroud, and they made their report the following year, after having examined thirteen processes, six of these commencing with the forma-

tion of sulphate of soda from common salt; and here is what they say in their report:—

“Citizens Le Blanc, Dize, and Shee (copartners) were the first who submitted to us particulars of their processes; and this was done with a noble devotion to the public good. Their establishment had been formed some time previously at Trainciade, but the consequences of the French Revolution, and of the war which followed it, having deprived them of funds, the works were suspended, and for some months past the manufactory had become a national establishment.

“This establishment had been erected entirely with the private funds of the partners. It would be difficult to collect together, in so moderate a space, more means and conveniences than are met with in this manufactory—furnaces, mills, apparatus, and magazines, all arranged in the best order for the convenience of the service.”

The report then gives a full description of all the various steps in the process that constitutes the invention of Le Blanc.

It is needless for me to detail how extended this soda industry has become, but will conclude this part of my subject by giving a chronology of the soda trade, as given by Gossage.

Chronology of the Soda Trade.

Period.	Raw material used, and prices.	Quantity manufactured.	Prices.
1790	Barrilla and kelp	Not known.	Not known.
1792	Le Blanc's process invented and applied in France	Not known.	Not known.
1814	Crystals of soda, made from } Bleacher's residua, and by Mr. } Losh from brine }		Soda crystals \$300 per ton.
1823	Mr. Muspratt's works commenced and using—		
1824	Common salt at \$ 4 per ton Sulphur at 40 " Lime at 4 " Coal at 2 "	Probably 100 tons per w'k of crystals & soda ash.	Soda crystals \$90 per ton, Soda ash \$120 per ton.
1861	Fifty works in operation in Great Britain using Le Blanc's process Raw material in Lancashire costing Common salt \$ 2 00 per ton Sulphur from pyrites 20 00 " Limestone 2 00 " Fuel 1 50 "	5000 tons per week.	Soda crystals \$22 per ton, Soda ash \$40 per ton.
1861	Annual value of produce \$10,000,000. Number of workmen employed in the manufactories 10,000, exclusive of those engaged in mining for pyrites, limestone, and coal; also those employed in navigation and other means of transport.		

The important bearing of the soda industry is the only excuse I have for so lengthy a reference to it, and I can only venture to touch upon two or three additional points in connection with it; the first is the recovery of the sulphur from what is known as the soda waste, thus making this agent to renew its function again and again in the production of soda. At present hundreds of tons of sulphur are recovered by processes well known to most chemists.

Another fact I must not omit is the employment of a large quantity of a mineral from Greenland called cryolite for the production of soda, and yet more recently the perfecting of what is known as the bicarbonate of ammonia process, by Salvay & Co., of Belgium, who in 1873 produced by this process 5000 tons of soda, employing 110 workmen.

Potash and its Salts.

Much of what has been said in relation to soda, is equally applicable to potash. This article, that was procured by the destruction of our forest, is now furnished in vast quantities and at a much lower rate from mineral resources.

The first one resorted to was the sea water, or rather the residual water after crystallizing out common salt for consumption in domestic economy and the arts. And one of the best methods of conducting the separation was devised by Balard, and is carried on to a considerable extent in France. But the great future source of potash is from the minerals sylvite, carnallite, kainite, and polyhalite, now discovered in great abundance in the salt mines of the Stassfurt, and other salt mines in the world.

The chemist converts the potash-chloride found in those minerals into the carbonate in the same manner as he makes the carbonate of soda from common salt.

Cyanide of Potassium.

This cheapening of potash of course gives new impetus to chemical industry dependent upon this alkali, among them the manufacture of cyanide of potassium, of which the most advanced chemistry is the manufacture of the cyanogen from its elements, although the practical application on a large scale still meets with considerable difficulty.

Oxalic Acid.

Another recent industry, sprung up from the application of potash in the caustic state, is the formation of oxalic acid by heating sawdust with it, there being usually employed with it a certain quantity of caustic soda, which latter alkali will not produce the required effect alone, although potash will, and the reason of the admixture with soda is to make the process more economical.

Soluble Silicates.

Cheap soda and potash have enabled the chemist to make on a commercial scale soluble glass. As an in-

dustry, it was started as early as 1825 by Fuchs, of Munich. But it has only been in latter years that its application has been extensive, and we are all now familiar with its use in hardening and preserving stone, preparing artificial stone, cement, etc.

Stearinery.

The next industry that demands our notice is that of stearinery and soap-making, and all that is important in connection with it belongs to the latter half of the past hundred years, and dates from the labors of Braconnot in 1817 in separating oleine and stearine, and were specially developed by the remarkable scientific researches of M. Chevreul.

That these labors deserve to be ranked so high, arises from the fact that they were made at the birth of organic chemistry, and on a most difficult class of bodies, about the nature of which there was no correct conception, and when the analysis of organic substances had been but just commenced. Still more, M. Chevreul did not give to the world the results of his labors as a mass of isolated facts, but he systematized and classified new acids, new bases, and left to us the chemical history of facts almost as fully made out as they are at the present time; and these have contributed as much, if not more than any class of researches to give direction and growth to organic chemistry. The decomposition of the fats and formation of the fatty acids developed the fact that, when melted and allowed to cool slowly, the more solid acids crystallized, so as to allow of easy separation of the solid from the liquid part, which fact soon suggested a practical application.

In 1823 a complete account of the labors of Chevreul was published; at this period fruitless efforts were made to manufacture stearic acid.

Importance of the Stearic Acid Industry.

It is difficult to render an exact account of the importance of the stearic acid industry; nevertheless it can be stated with certainty that the annual production for France is 50,000,000 of pounds, and approximately

for the remainder of Europe is 200,000,000 pounds, and for America 20,000,000 pounds.

The largest candle factory in the world is that known as the Price Company, having its principal establishments at Liverpool and London, with a capital of \$5,000,000. The great steps in the progress of this industry were first made by Gay-Lussac and Chevreul in 1825, who first thought of applying the fatty acids for illumination, forming them first by saponifying the fats by alkalies or the alkaline earths, decomposing by acid, and separating the solid and liquid acids by pressure.

It will be seen that this process is deduced directly from the theoretical researches of Chevreul, with the important exception in relation to saponifying under high pressure.

The process of Chevreul and Gay-Lussac was not considered at the time capable of being brought into practice in the arts from their using potash and soda, thus making the product a very expensive one.

Besides the above difficulty in the original development of stearic industry, another arose in the very commencement, viz., that when candles were made with the ordinary wick, they burnt very imperfectly, and the inventors above referred to devised wicks of peculiar description that answered the purpose more or less perfectly. But prior to them J. L. Cambaceres devised similar ones, and subsequently improved upon them, and finally settled upon the plaited wick now in common use in all stearic acid factories.

The next important step rendering the stearic acid industry a success, was also made by M. Cambaceres, viz., the separation of the oleic acid by powerful pressure, first on the mixed acids cold, and subsequently warmed; and he established a factory in Paris to carry out his process, but this soon failed, from the inferior nature of candle-stock produced, and the expense of its production, potash being employed by him as the agent for decomposing fats.

For several years this industry was abandoned, as being a difficult and unprofitable one, when in 1829, two young physicians, De Milly and Motard, took the sub-

ject up, and after two years of laborious and persistent study of it, accomplished the problem of the successful manufacture of candles from the fatty acids. It is only simple justice to say that the names of Chevreul and De Milly go side by side in this industry, and the first in his theoretical discoveries, and the latter in his ingenious and successful devices in the accomplishment of great practical results.

A second advance in this industry was the use of sulphuric acid to decompose the fats, which originated also with Chevreul and Gay-Lussac, but was not successfully carried out until combined with the distillation of the fatty acid after the decomposition—a method first executed by Dubrunfaut, and successfully carried out by Coley, Jones & Wilson, and subsequently perfected by Gwinne & Jones.

The next step made in stearinery was the decomposition of the fats by water. The conception of this method, in common with all the methods of saponification of fatty bodies, is to be referred back to the author of the discovery of the true nature of fats, M. Chevreul, for in his original researches he pointed out the perfect analogy between the fats and the compound ethers, the latter class of bodies being decomposed into their two constituents, in the presence of water heated in close vessels under pressure; a reasonable deduction from which was, that fats would undergo an analogous decomposition. This, however, was not undertaken at the time, but, by an accident about the time of Chevreul's researches, it was observed to take place by Faraday when his attention was drawn to some changes in oils used by Perkins in his curious steam engine that employed very hot water.

No attempt was then made to draw any practical results from these observations, and we find no further notice taken of the subject until early in the year 1854, by R. A. Tilghmann, of Philadelphia, when patents were taken out by him for decomposing fats mixed with water, and superheated in vessels of a certain description. The method of Tilghmann, as originally patented, was never introduced into practice; since then,

with change in the manner of operating, and in the nature of the boiler, it has been successfully conducted in many factories.

In the latter part of the same year that Tilghmann's process was patented, M. Melsens, of Belgium, took out a patent very analogous, using fats mixed with water in the proportion of twenty to one hundred per cent. of the latter; the water might be acidulated with from one to ten per cent. of sulphuric acid, or the addition of salt would suffice; the whole was heated from 180° to 200° C., for several hours. The success of Melsens's process was immediate, and it was put into operation on a large scale in Antwerp, in vessels holding one ton of tallow, to which was added fifty per cent. of water, and in six hours the decomposition was complete at a temperature of 180° C. (ten atmospheres). The fatty acids thus made were of a very satisfactory quality, quite as much so as those obtained by other methods of saponification.

But I would here say that this method, by superheated water, is now supplanted by a mixed method of using one or two per cent. of lime with the superheated water, which addition facilitates and hastens the reaction in a manner not yet understood by chemists.

Glycerine.

This new art of stearinery assumed such dimensions, that the chemist sought to utilize all by-products connected with it. The oleic acid or red oil, as is well known, is used for various purposes, principally for forming soap.

The candle-makers at first allowed the glycerine produced, to run to waste. This sweet principle of the fat was first discovered by Scheele in 1873, and afterwards studied by Chevreul in 1819, and its true nature ascertained, as a triatomic alcohol of the radical glyceryle, now having a well-defined place in organic chemistry. But, like everything connected with the art of which we are speaking, some minds were directed to examining and purifying it, and when presented to the world abundantly in its pure form, some application was

sought for it, and its use became extended day by day. The principal features connected with the improvement in its manufacture, relate to its distillation, and still later to its purification by crystallization by Sarg, and in 1871 he purified in this way twenty-five tons. As for its application it is more varied than that of any other substance springing from the chemical arts. It is used in wine-making, beer-making, confectionery, liquors, in cloth-making, in calico-making, in preparing leather so as to remain supple and durable, in the tobacco factory, for lubricating delicate machines and firearms, etc., preserving organic matter, filling gas meters to prevent the effect of cold, for making rollers for printing presses, in the art of perfumery, in medicines, etc.

Nitro-glycerine.

But of all the applications of glycerine, the most curious one is that of making an explosive compound for blasting rocks, etc., of which there are now not less than seventy or eighty tons consumed annually.

In 1847 an Italian chemist named Sobrero, working in the laboratory of Pelouze, discovered that the action of concentrated nitric acid or a mixture of nitric and sulphuric acid upon glycerine produced a peculiar oily liquid, having among other properties that of exploding when struck by a hard body, or when heated. At first it was only regarded as one of the many curious compounds that are born every day in the chemical laboratory. Any practical application was not thought of, for the glycerine then was too expensive a substance to enter into competition with other substances used in making explosive compounds. It was reserved for a Swedish chemist named Nobel to make an application of this oily compound called nitro-glycerine, and by improvement in the process of its manufacture, and the consequent impulse it gave to the separation and purification of glycerine, it is now a substance of every-day use by those engaged in mining and in large engineering works, requiring the removal of large bodies of rocks; and, notwithstanding it is an extremely dangerous substance to handle, and many lives and much

property have been destroyed by it, contractors on large works say that they prefer using it to gunpowder, with all its attendant risks.

Gun-cotton.

Gun-cotton is another of those curious chemical triumphs of the past few years of chemistry. It was never imagined that this well-known and useful vegetable fibre called cotton, could be so easily converted into one of the most powerful explosive compounds known, and would serve as an article of offensive and defensive warfare. The first announcement of its discovery was in 1845 by Prof. Schönbein, of Basle, and almost at the same time by Böttger, of Frankfort. Its powerful explosive nature was made very manifest early in the establishment of its industry, by two very disastrous explosions, one in 1847 in the gunpowder factory of Messrs. Hall Brothers, where they were making gun-cotton, and the other in July, 1848, where 3500 pounds of this substance exploded at Bouchet near Paris. These and other accidents so alarmed the public that its manufacture was suspended, especially as some of them appeared to arise from spontaneous decomposition of the gun-cotton. But as it is a part of the code of chemical ethics not to be frightened at anything, especially at a creature of its own creation, they went to work at once to discover causes and remedies, in which as usual they succeeded, so much so that at the present time a number of batteries of artillery in the Austrian service use gun-cotton. It is employed largely by the English government in their military service, under the efficient direction of Prof. Abel. It is also used for blasting in quarries.

The most recent development, however, in connection with it, is that it can be exploded efficiently when wet, by the aid of a fulminating fuse, which fact, if properly borne out by sufficient experience, will increase its value, in so far as it increases its safety of transportation, etc.

I must here refer to a curious property of gun-cotton, viz.: its solubility in ether, or a mixture of alcohol and ether, producing a solution called collodion, which is the

menstruum used by photographers for placing the chemical materials on the surface of the glass to receive the action of the light in the preparation of what are known as negatives. It was first used for this purpose by an English photographer named Archer, although the collodion had been prepared some time before by Dr. Bigelow, of Boston, and used in the surgical treatment of wounded surfaces. The value of gun-cotton as a photographic agent cannot be overrated, when we remember the ramifications of this art in social life and scientific pursuits; in this latter direction it is especially valuable to the astronomer.

In strict justice I should class the art of photography as one of the chemical industries created during the past hundred years, for every step in its invention, application, and future development depends on chemistry; but we must be satisfied with a simple mention of it.

Chemical Industry of Coal.

I will not delay calling the attention of my audience to a chemical industry pre-eminently one of this century, and, curious enough, it does not owe its origin to either chemistry or to a chemist, yet in its developments some of the ablest chemical talent in the world has been and is still engaged. I allude to the chemical industry of coal.

It was started by two individuals of practical mind, Murdock in England and Le Bon in France, who sought to control the gaseous products emanating from burning coal in such manner as to be useful for illuminating purposes, and from the year 1800 to the present time it has been used successfully for that purpose, and all the large cities of Europe and America, and numerous small towns, give evidence every night of the universality of its use, dispensing comfort all around.

Its direct effect is to convert night into day, to make the short and obscure winter days equal to those of summer, giving more time to those occupied with indoor pursuits, and enabling them to conduct their labors with less fatigue to the eye and with more certainty of execution. In this aspect alone the immense wealth that has been added to the industrial arts is incalculable.

In its indirect effects, the use of coal-gas has benefited society by saving vast tracts of land for other agricultural purposes that would have to be devoted to the cultivation of plants furnishing oil and fatty matters, to be used for illumination, and, besides, there have been saved for other purposes hundreds of ships and thousands of seamen that would be required for the whale and other fisheries carried on simply for the purpose of procuring oily matter to be used for furnishing light.

Regarded as a luxury, its benefits are not to be despised, for it has cheapened many of them to such a degree that both rich and poor are equal participants of them. Our brilliantly lighted streets are evidence of this fact, so that the people traverse our cities with the same ease and security at night as in daytime. And here we may again allude to another fact in connection with the manufacture of coal-gas, namely, that the offensive residues which are the natural results of gas-making have been made to give rise to most important industrial pursuits, employing a large amount of capital and labor and accumulating much wealth.

But it has been left for the more recent developments of chemistry to extract from the residues of gas-making, by processes more or less indirect, beautiful crystallized compounds used in giving to silk, wool, and cotton colors that rival in brilliancy the hues of the rainbow; and this discovery in its turn reacts on the manufacturers of the various textile fabrics.

In the making of gas from coal three great residual products are formed, consisting of coke, ammoniacal liquor, and tar, the last two of which were cast away as refuse, but now, under the directing mind and skill of the chemist, they have been converted into most useful products, the ammonia being collected and condensed in such form as to be made serviceable for all purposes in the arts and agriculture, which latter industry now depends very much upon it in giving the requisite nitrogen elements to artificial manures.

But it is from the coal-tar that the chemists, during the past fifteen years, have reaped a harvest of wonder

ful chemical results; from it they have extracted not less than seven acids, fourteen alkaline substances, and ten neutral bodies, and with many of these they have wrought such wonderful metamorphoses that chemists themselves, accustomed though they be to strange transformations, are amazed at the results of their own investigations

As much as we might desire, we have not time to dwell upon progressive discoveries that led to the first aniline color in 1856, by Hofmann and Perkins, and will only state that in the short period which has elapsed since then, the chemist does with the tar of gas-works what the rain drop does with white rays of the sun, viz., unfolds all the beautiful colors of the spectrum, red, orange, yellow, green, blue, indigo, and violet: first came the mauvine and rose aniline in 1856, then the aniline red in 1859, then the aniline blue in 1860, then the aniline green in 1863, after that the violets of methylic and ethylic rosaniline, and aniline black.

And now our beautiful dyes are no longer brought from the tropics and the Indies, but Europe sends to China, Japan, and the Indies dye-stuffs, and sends artisans to show to those nations how to apply those dyes: the moneyed value of the present product being about \$10,000,000. Is this no triumph for the industrial chemistry of the nineteenth century? Nor have we arrived at the end of this matter of the chemical industry of coal. That most valuable substance, alizarine, the coloring principle of madder, had defied the chemist's skill to imitate and produce by artificial means. With the chemist, to accomplish it was only a matter of time, and about five years ago we had the first announcement of the production of alizarine from one of the coal-tar products (but little known and of no commercial value up to 1870). So rapidly has this branch of industry grown, that, during the last year there was put into commerce 1000 tons of artificial alizarine dye, with a standard of 10 per cent. of alizarine, worth upwards of four millions of dollars, one-half of which was produced in Germany. So that now the agriculturist engaged in madder cultivation is fearing the supplanting of madder

altogether by this new chemical industry, which furnishes to-day nearly one-half the alizarine dyes.

Phosphorus and its Applications.

In phosphorus and its applications we have a chemistry of small things, but an industry of great magnitude. In the words of another, "Phosphorus is a singular instance of an article, discovered one or two centuries ago, which, until recently, possessed very little interest but to the professional chemist, and more rarely to the physician; but which, by an application dating back little more than thirty years, rapidly became an object of large manufacture, and is now, in the everywhere indispensable lucifer-match, carried not merely over the civilized world, but to every land which possesses any commercial intercourse.

"The Dutch chemists, who laboriously first drew it forth in minute quantities, and by a tedious process from urine, little thought that this substance, so distinguishable from its self-inflaming qualities, would, in after time, be manufactured by hundreds of tons, and be not only found in every household, but made the kindling spark of all hearths in every civilized country. One of the largest manufacturers of phosphorus, when he underwent training, only knew phosphorus by a small stick two inches long that was in the laboratory in which he studied. He now draws it out by machinery in a cord many miles in length, and sends it off by tons to all parts of the world." The improvements in the method of manufacture, and the amount of consumption, are best realized when you are told that upon the introduction of its use in the manufacture of lucifer-matches, its price in England was \$20 per pound, while the price now does not exceed 75 cents to \$1 per pound; this economy of production being brought about by improved chemical processes, and by operating upon cheap and accessible material. There now exists some twelve or fifteen large factories, one-half of them in Germany, from which most of the phosphorus used in this country is imported.

The quantity produced is not less than a half million

of pounds, nearly the whole of which is consumed in the manufacture of matches, one-half the above quantity being consumed in Germany for that purpose. In the chemistry of phosphorus, the most remarkable triumph is that of Schrötter, about fifteen years ago, in producing what is called amorphous phosphorus, which is now well known to all chemists, and is used extensively in the art of match-making; this wonderful change in phosphorus being produced on a large scale, and its inflammability so altered as to allow of its being handled with impunity.

It is not volatile or subject to slow combustion, and does not poison the atmosphere in which the makers of matches are obliged to operate, and does not produce that peculiar and painful disease of the jaw, which ultimately produces caries of the bone, to such an extent, in some cases, as to necessitate the removal of a large proportion of the jaw; showing that the aim of chemistry is not only to increase and improve the materials for the use of society, but to present them in such form as not to injure the health.

Iodine and Bromine.

Of iodine and bromine I have but little to say, although both their discovery, and their chemical industry have been the growth of the past fifty or sixty years. This neglect does not arise from their lack of importance, for they both rank as articles of prime necessity in several of the most important arts, as well as important curative agents in disease. There has been much improvement in the art of extracting both iodine and bromine from their raw materials, and coal naphtha has become an important agent in facilitating the separation of the iodine, or rather in collecting the iodine once separated by chemical agency. Also the Peruvian nitre has now become an important source of this substance. As for bromine, its production is increasing every year both in this country and in Europe.

Sodium, Aluminium, and Magnesium.

While sodium, aluminium, and magnesium do not perform as yet very important functions in the arts, they

are produced on no inconsiderable scale, and are conspicuous examples of how mere laboratory methods may be rapidly developed into industrial processes when directed by the skill and ingenuity of able chemists. In this particular instance we are indebted to M. St. Clair Deville, than whom there is no more ingenious chemist in working out difficult problems in the metallurgy of the rarer metals.

The production of these metals in quantity has given new agents to the arts, and sodium amalgam is now well known in metallurgic operations on gold. Aluminium and aluminium bronze have found their use for many valuable purposes, and magnesium is much valued for signal and rocket purposes.

Medicines.

But of all the benefits derived from the growth of mere laboratory processes into grand manufactural operations, none can claim more than the art of medicine, for she has received her full share, as we all well know, and as is every day shown by the operation upon cargoes of Peruvian bark to extract that valuable medicine quinine, and the elimination of thousands of pounds of morphine from opium; and, still more recently, the unfolding of the hidden treasures of the chemist has brought to light chloroform and chloral, the earlier specimens of which he valued as gold or silver, while now they are thrown upon commerce by thousands of pounds, alleviating an untold amount of suffering; and these great blessings are afforded mankind as a free-will offering of the skill and industry of the chemist, for he invokes no patent laws to make money from these precious gifts of God, whose high priest he is in one sense, having been favored by the divine dispenser of all good to make known these things to man.

The review just given of the chemical industry of the past hundred years, is but a notice of the salient points in connection with its history and progress. No mention is made of the art in connection with the working of iron, copper, and other metals, for that now takes rank almost as an independent art, called metallurgy,

but it is none the less chemical in its character, and, as chemistry progresses, so will this art. The same may be said in regard to glass-making, photography, electrotyping and gilding, and numerous other arts which must have presented themselves to your minds during this discourse.

But I must not detain you longer, and shall conclude by congratulating you that we are living in an age in which an industry requires but a few years for its creation or development.

"In our days a useful discovery is scarcely made, or a happy application of one found out, before it is published, described in the scientific journals, or other technical periodicals, and especially in the specifications of patents. It then becomes the starting-point of a thousand researches and new experiments, entered into by the philosopher in the hope of advancing scientific progress, and by the manufacturer with the expectation of reaping a material benefit. From these multiplied and diverse efforts—these incessant labors of an army of workers—arises an industry which has no sooner sprung into existence than it becomes important and prosperous."

So then let us, American chemists, bend all our energies to do full share of this work. Up to the present epoch our short existence as a nation, and some other causes, have forced us to be the recipients of the numerous discoveries of our European co-laborers without an adequate return on our part; but there will be no such excuse for the future if we do not stand side by side with them in the developments of industrial chemistry.

